UNIVERSITY of VIRGINIA

Power Management Solutions for ULP SoCs

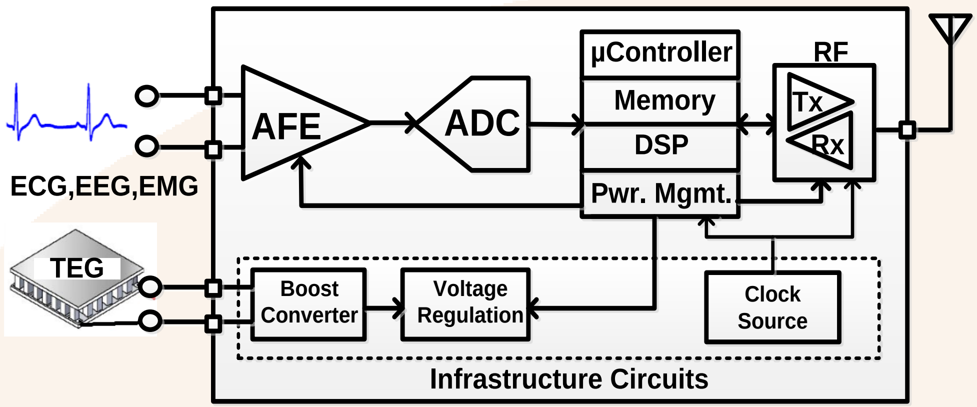
Deliberate Practice – Session 3

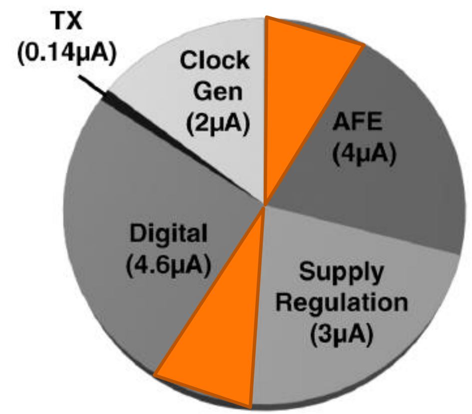
Seyi and Aatmesh

15th May 2013

ROBUST LOW POWER VLSI

Session 2 Review





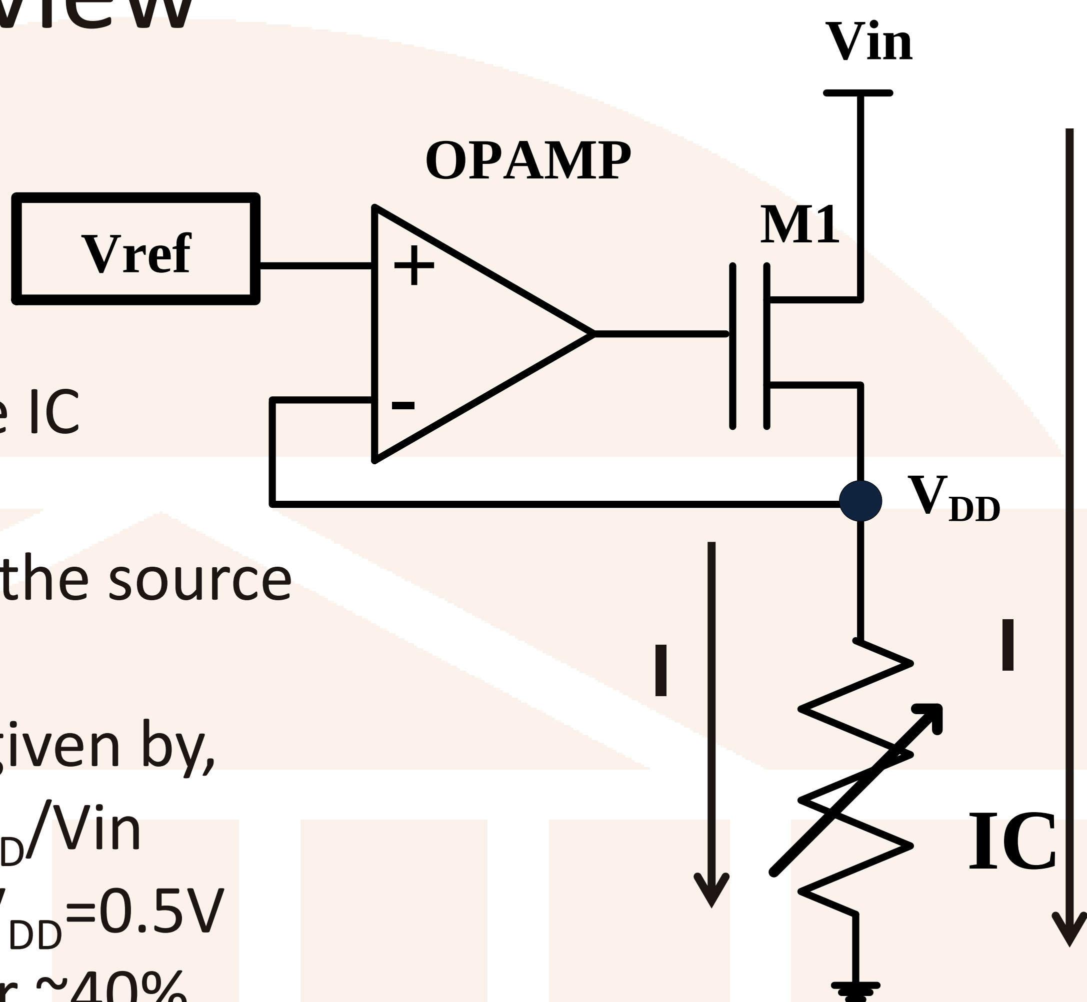
19μW out of 50μW from TEG

Y. Zhang, et al, "A Batteryless 19uW…. ", JSSC, Jan. 2013.

- Problems with Power Management in ULP SoCs
  - **Efficient voltage regulation required at low voltages**
  - **Multiple regulated output voltages needed**
  - **Energy harvesting is needed to further extend lifetimes**

Session 2 Review

LDO



- Input power to the IC
  - V_{DD}*I
- Power taken from the source
  - Vin*I
- Ideal Efficiency is given by,
  - V_{DD}*I/Vin*I=V_{DD}/Vin
- Ex, Vin=1.2V and V_{DD}=0.5V
- Efficiency is 0.41 or ~40%.
- **Almost 60% of power is lost in regulation**

Session 2 Review

Research Questions

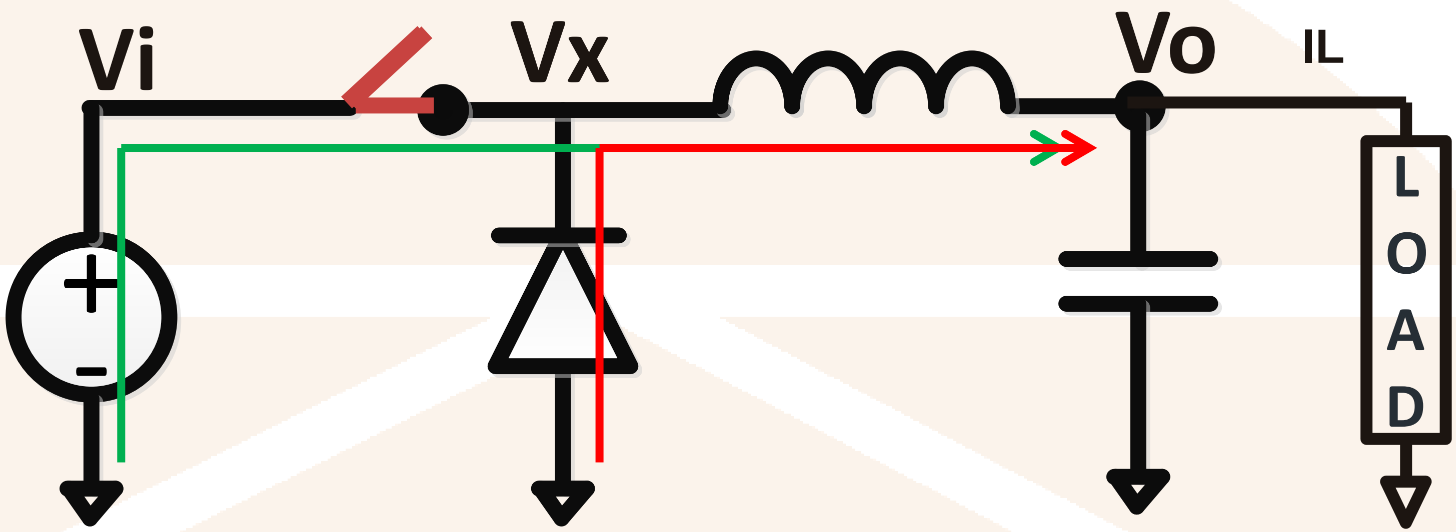
- What alternatives to an LDO can we implement to raise the intrinsic efficiency of the regulator?
- How will these alternatives address other problems?
  - Multiple outputs
  - Overhead (area, power, etc.)
- How will energy/performance be monitored?
  - e.g. DPM (Shakhsheer et. al.)
- How can we harvest energy with higher efficiency?
  - State of the Art: 38%

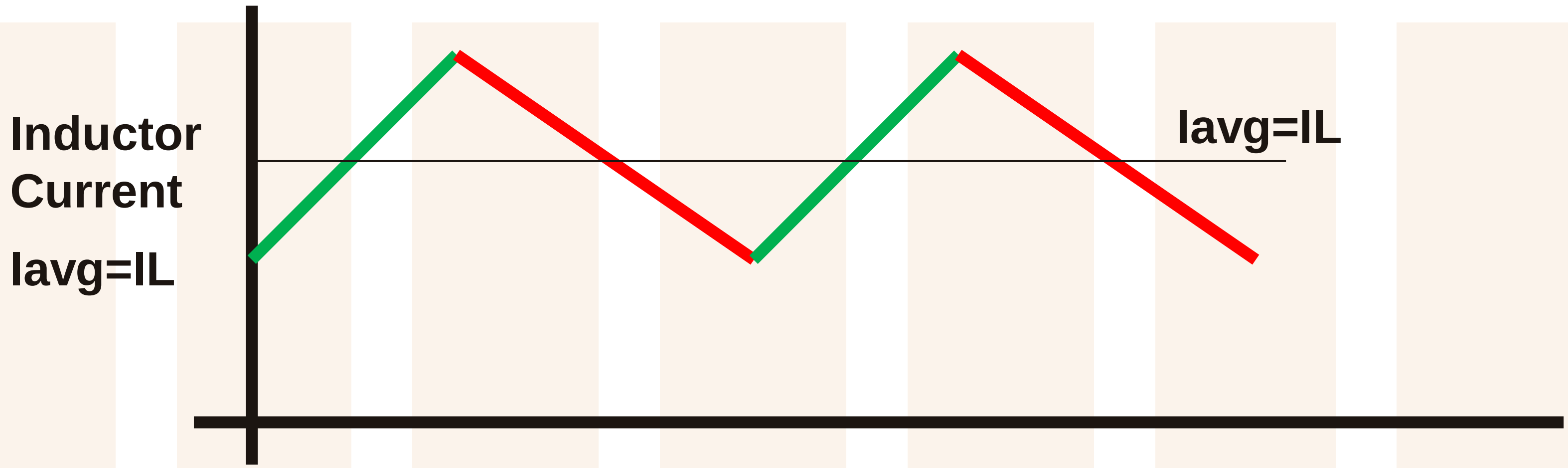
Proposed Solution – Modified DC-DC Converter

<u>Title</u>: **A 400nW <u>Single-Inductor Dual-Input-Tri-Output DC-DC Buck-Boost Converter</u> with Maximum Power Point Tracking for Indoor Photovoltaic Energy Harvesting**

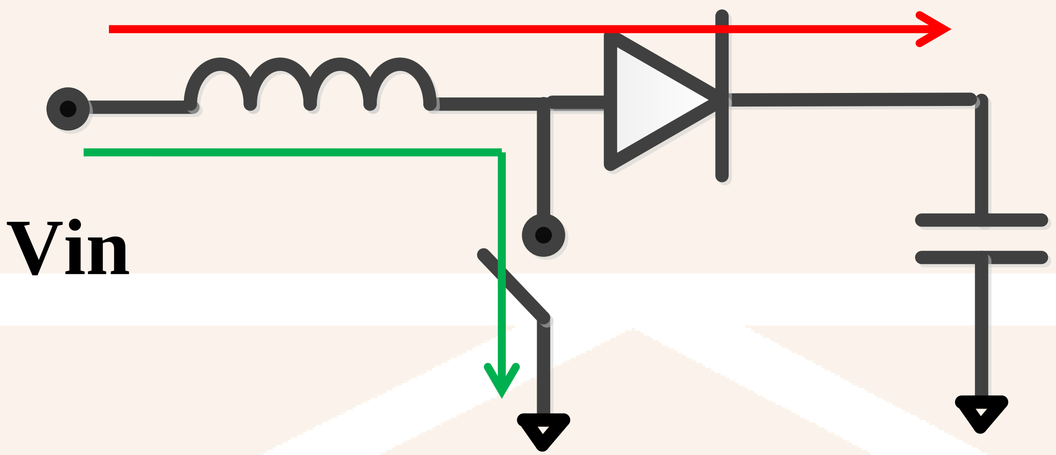
<u>Authors</u>: K. Chew, Z. Sun, H. Tang, L. Siek

DC-DC Converter Review: Buck

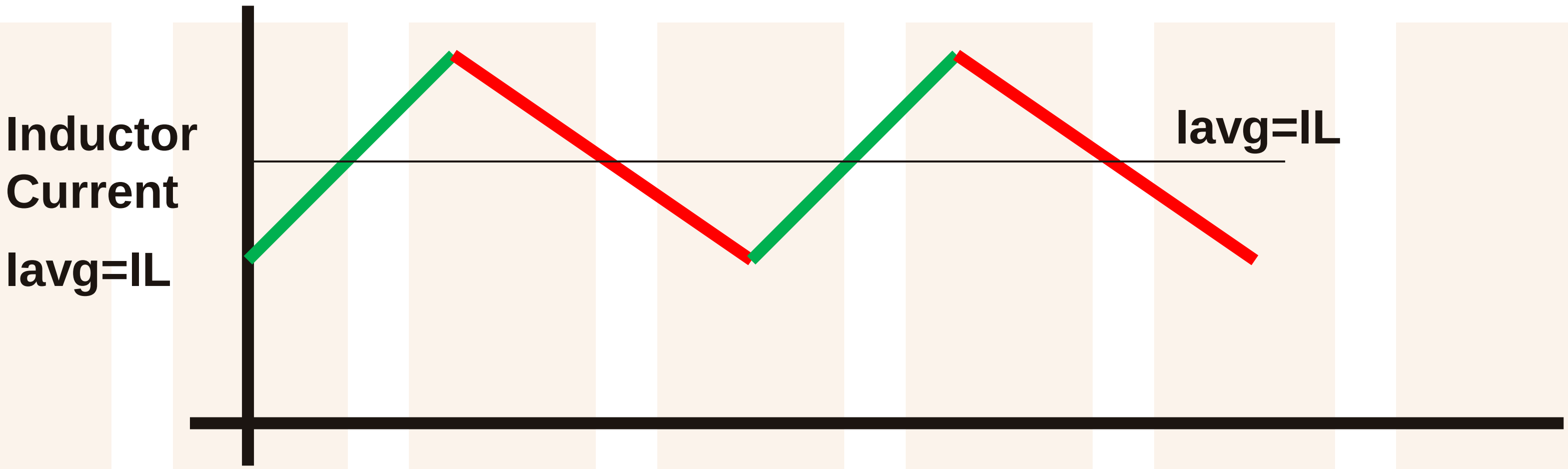




Boost Converter

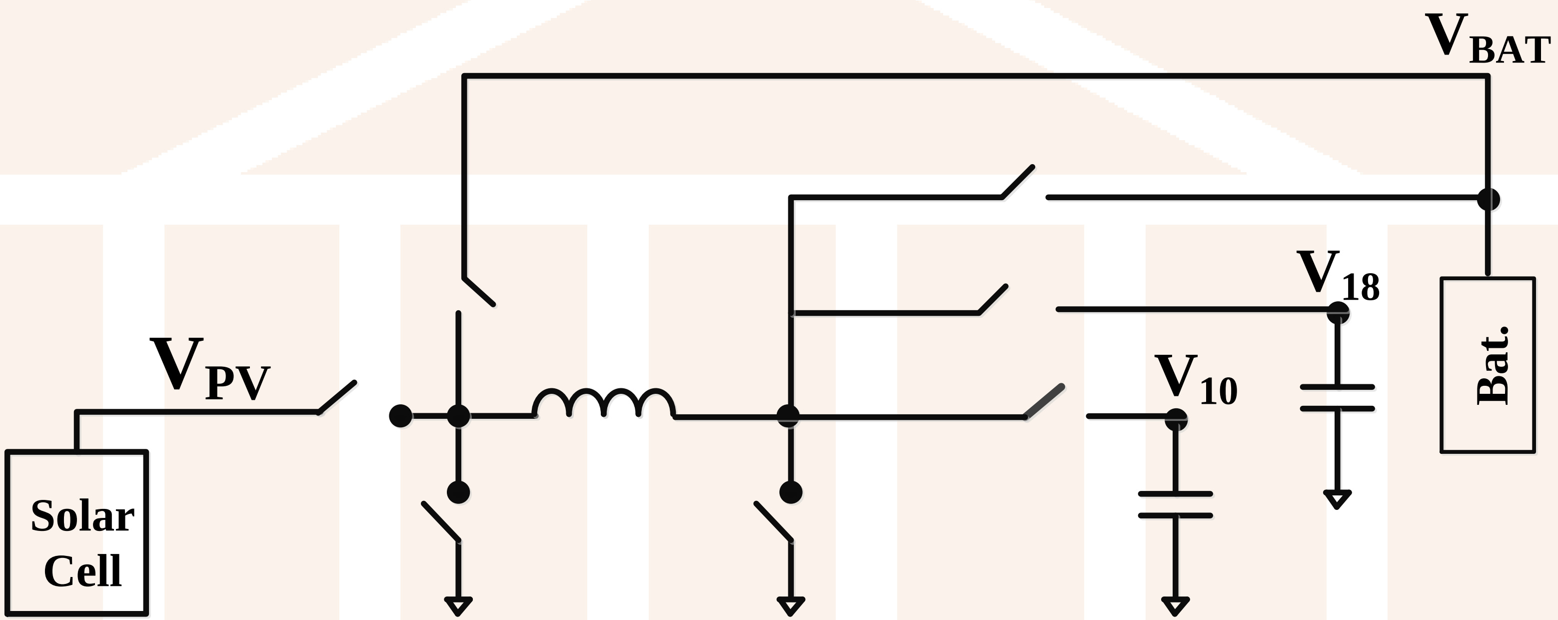


Boost Converter



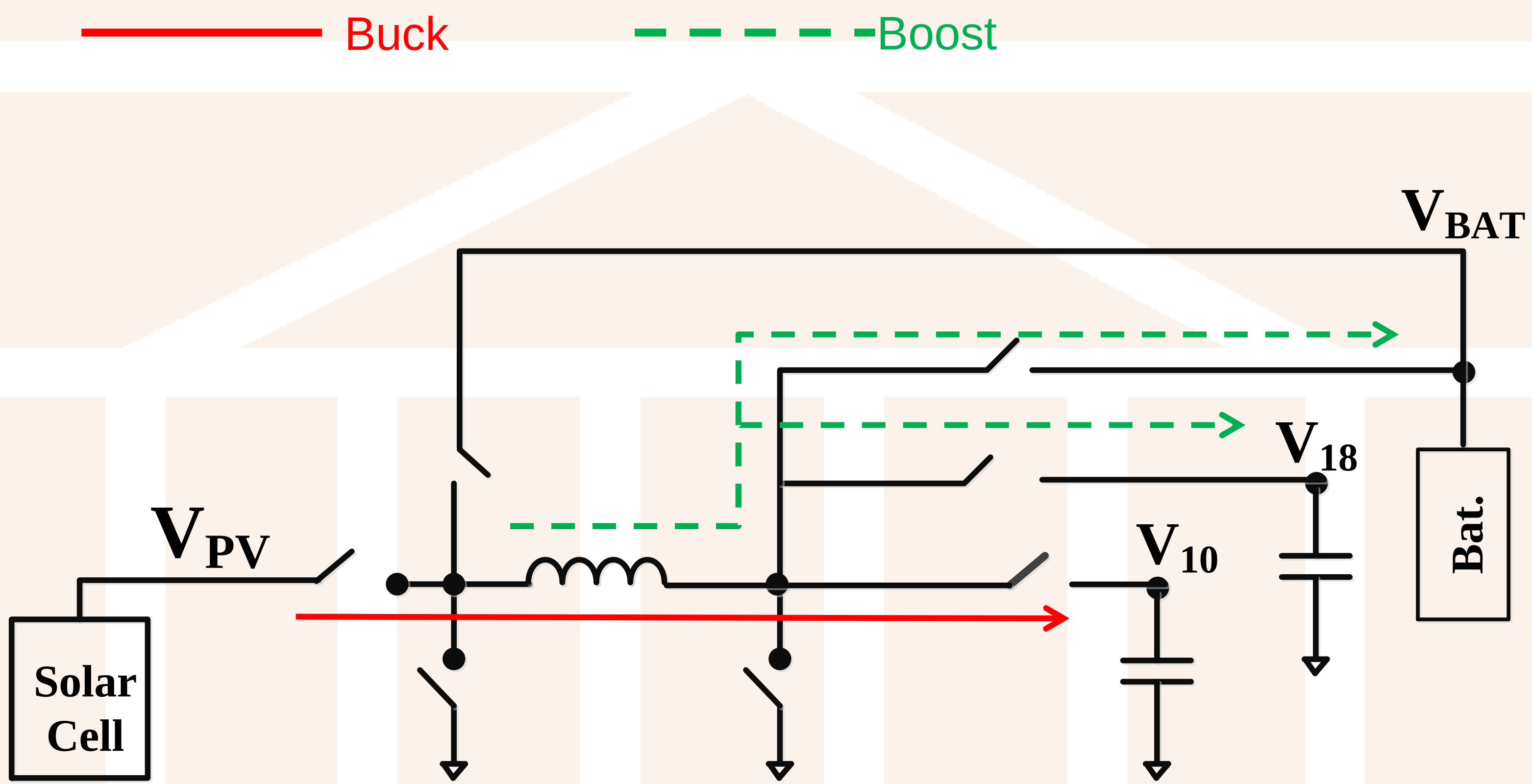
Proposed Solution – Modified DC-DC Converter

- Dual-Input Tri-Output
  - Allows three rails and two energy harvesting options

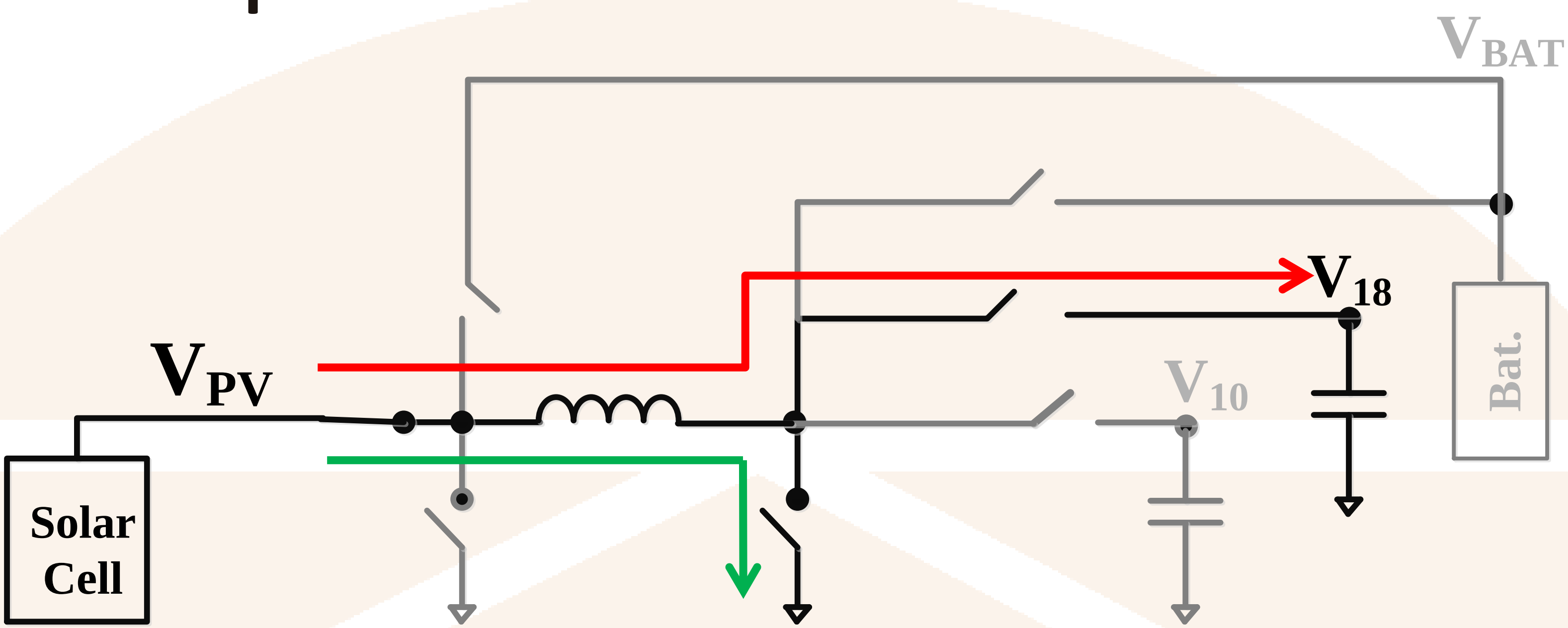


Proposed Solution – Modified DC-DC Converter

- Both Buck and Boost Conversion with single inductor

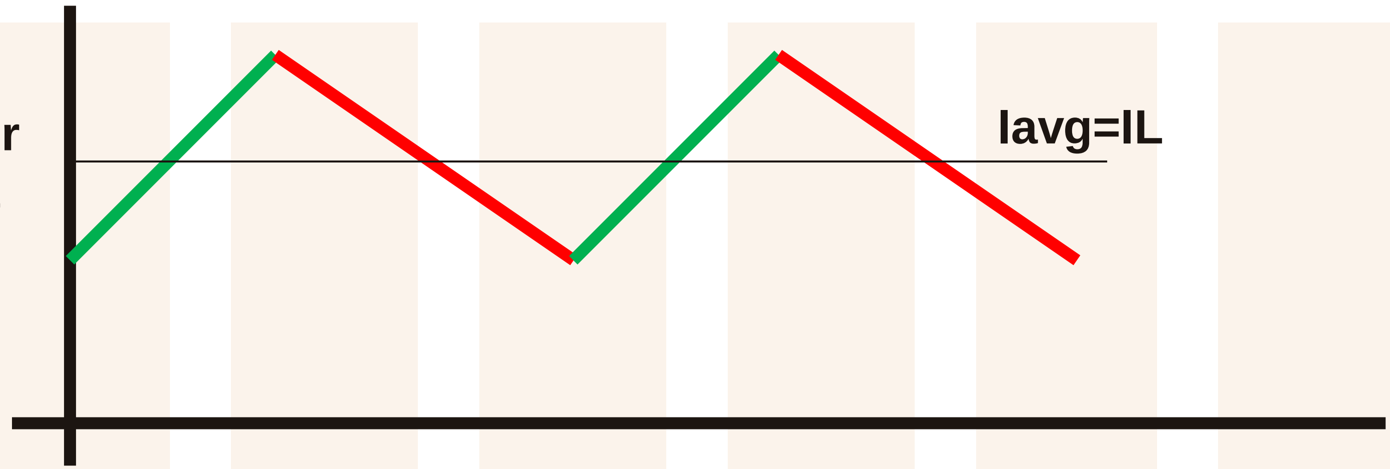


Example – Boost Converter



Inductor Current

Iavg=IL



Proposed Solution – Modified DC-DC Converter

<u>Title</u>: **A 400nW Single-Inductor Dual-Input-Tri-Output DC-DC Buck-Boost Converter with <u>Maximum Power Point Tracking</u> for Indoor Photovoltaic Energy Harvesting**

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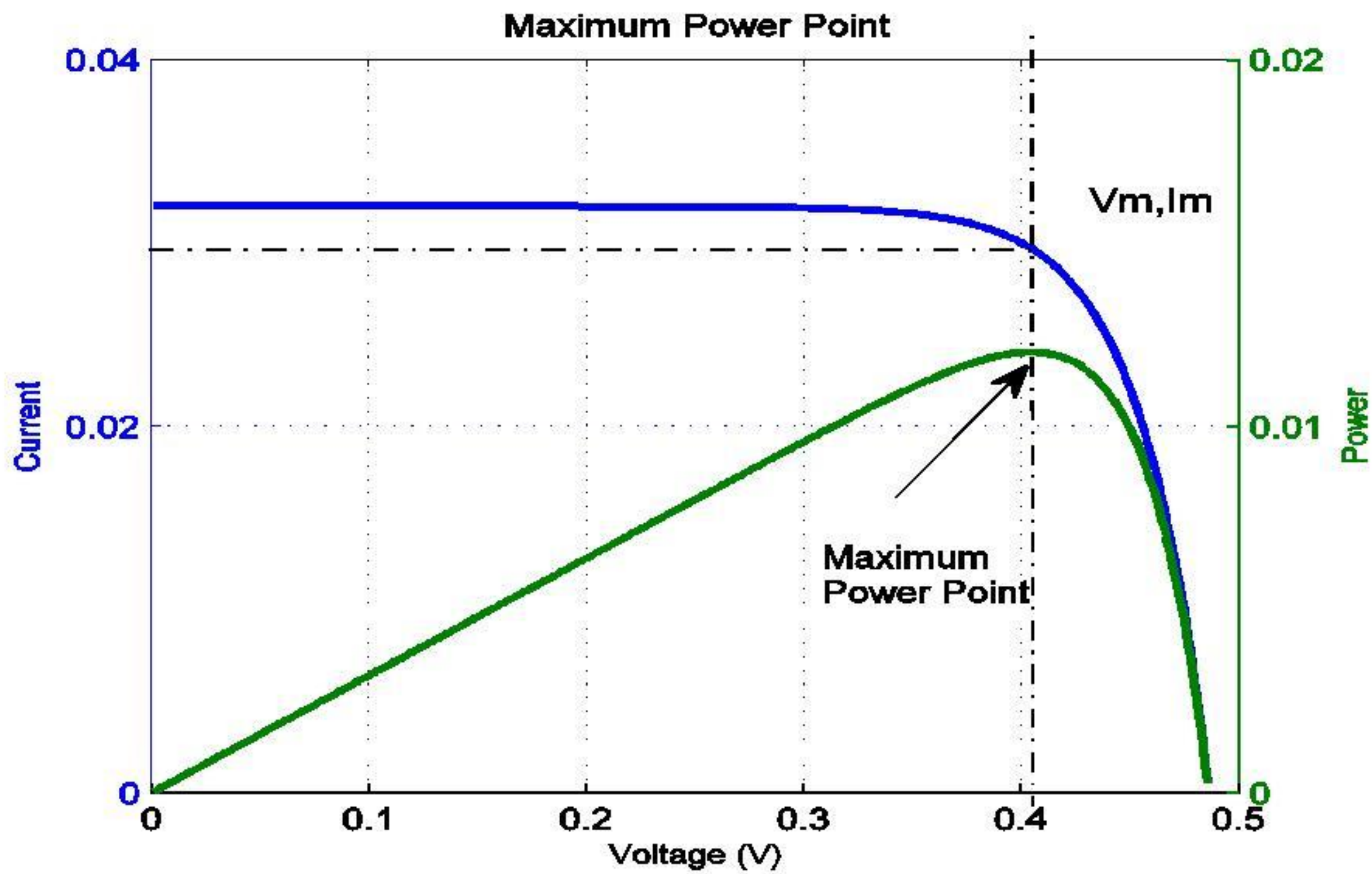
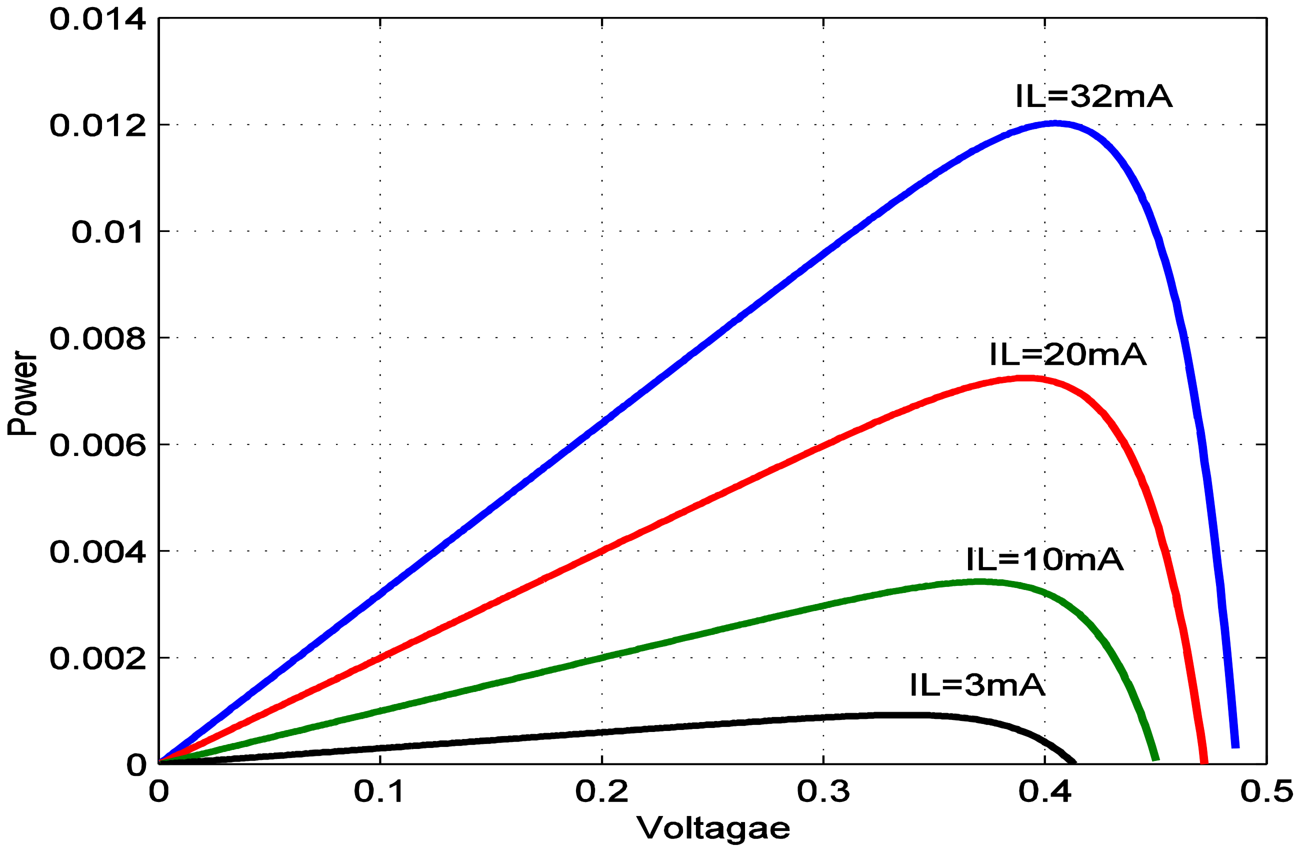
Energy Harvesting for using Solar Cell



- Maximum Power Point (MPP) exists

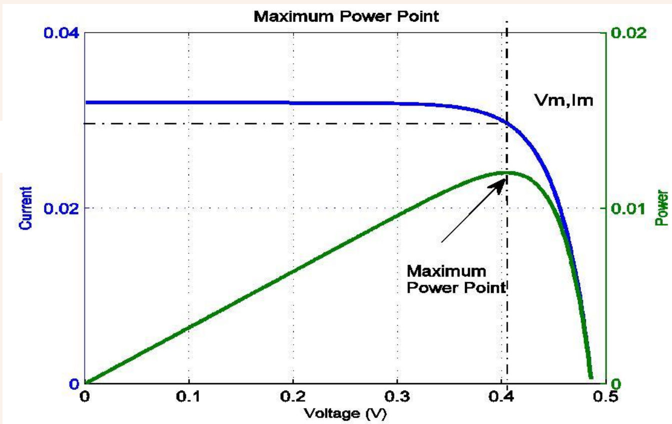
MPP is a dynamic quantity

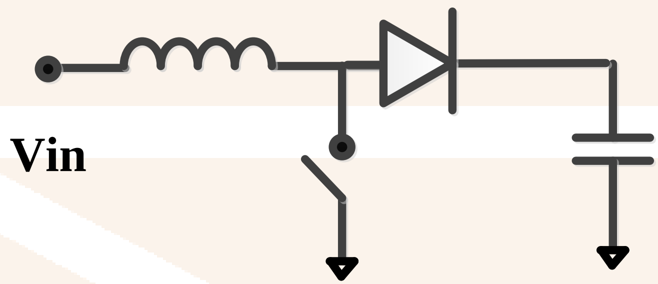


- MPP varies with insolation level, temperature etc.
- MPP tracking needs to be done we need to operate at MPP

Maximum Power Point Tracking

How can this be done?

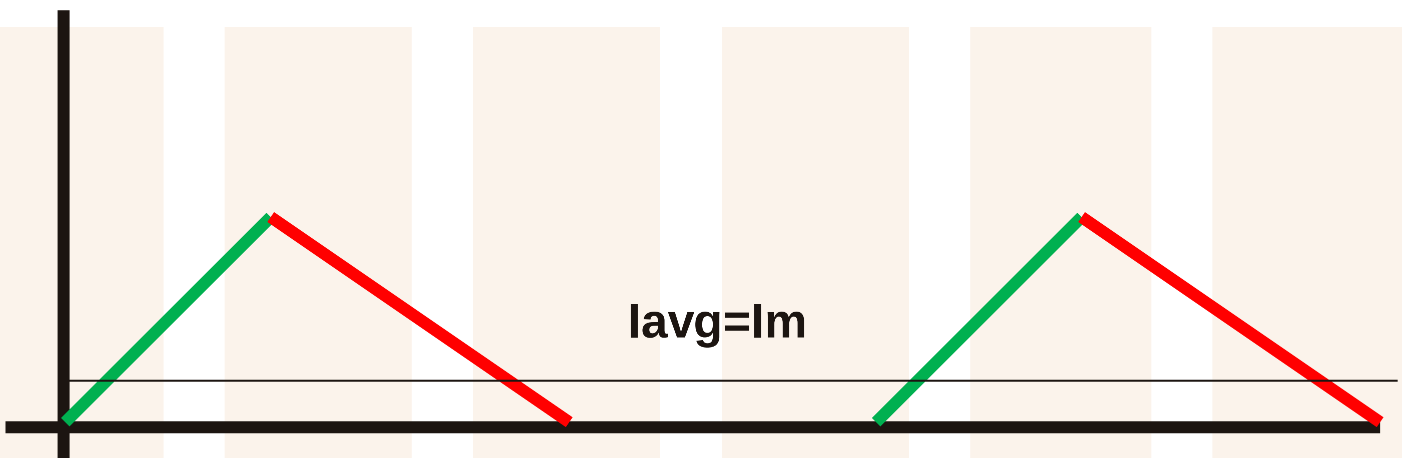




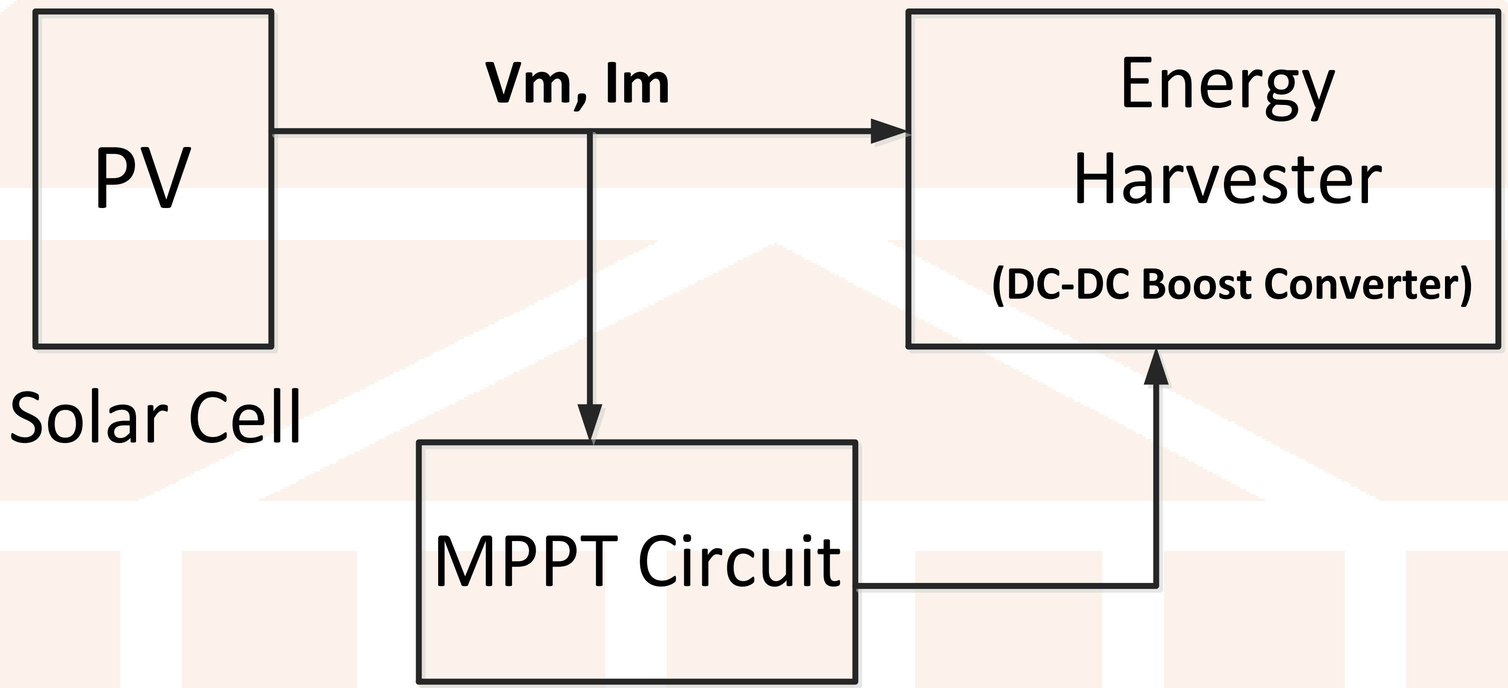
Boost Converter

Inductor
Current

Iavg=Im



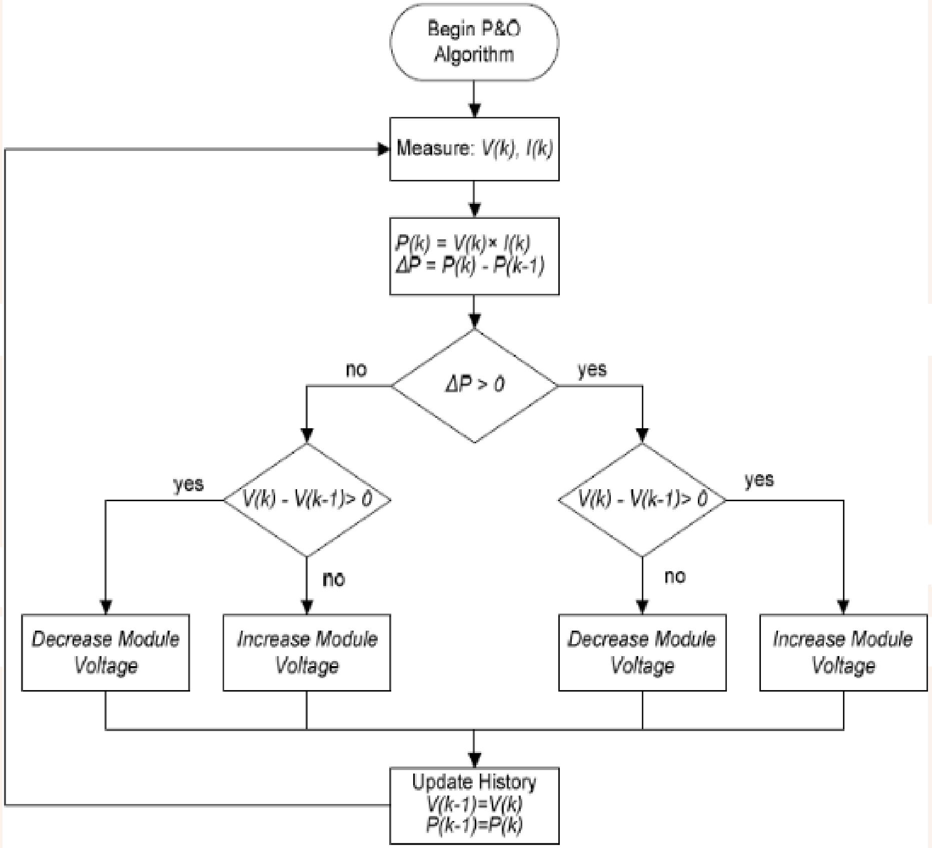
MPPT Implementation Block Diagram



Perturb and Observe (P&O)

- Paper uses perturb and observe method

Algorithm for P&O Technique



J.J. Nedumgatt, K.B. Jayakrishnan, S. Umashankar., D. Vijayakumar, and D.P. Kothari, "Perturb and Observe MPPT Algorithm for Solar PV Systems-Modeling and Simulation." *India Conference (INDICON), 2011 Annual IEEE, Dec. 2011 pp.1,6, 16-18*.

Results

	[3]	[4]	[2]	Discussed Work [1]
Output voltage	2V	5.5V	3V	1V, 1.8V and 3V
Output power	10µW to 1mW	621µW	5µW to 10mW	1µW to 10mW
Power consumption of control circuit	2.4µW	135µW	1.95µW	0.4µW
Architecture	Integrated charge pump	Inductive boost converter	Inductive boost converter	Inductive buck-boost converter
Peak conversion efficiency	70%	76%	87% (w/o MPPT) 70% (with MPPT)	83% (with MPPT)

References

1. Chew, K.W.R.; Zhuochao Sun; Tang, H.; Siek, L., "A 400nW single-inductor dual-input-tri-output DC-DC buck-boost converter with maximum power point tracking for indoor photovoltaic energy harvesting," *Solid-State Circuits Conference Digest of Technical Papers (ISSCC), 2013 IEEE International* , vol., no., pp.68,69, 17-21 Feb. 2013

2. Y. Qiu, C. Van Liempd, B. Op het Veld, P.G. Blanken, and C. Van Hoof, “5μWto-10mW Input Power Range Inductive Boost Converter for Indoor Photovoltaic Energy Harvesting with Integrated Maximum Power Point Tracking Algorithm,” ISSCC Dig. Tech. Papers, pp. 118-119, Feb. 2011.

3. I. Doms, P. Merken, R. Mertens, and C. Van Hoof, “Integrated Capacitive Power-Management Circuit for Thermal Harvesters with Output Power 10 to 1000μW,” ISSCC Dig. Tech. Papers, pp. 300-301, Feb. 2009.

4. Y.K. Tan and S.K. Panda, “Energy Harvesting from Hybrid Indoor Ambient Light and Thermal Energy Sources for Enhanced Performance of Wireless Sensor Nodes,” IEEE Trans. Industrial Electronics, vol. 58, no. 9, pp. 4424-4435, Sep. 2011.